gratifying exception. It stands, indeed, at the very apex of all the work that has been done upon the Coccidæ.

It is not that "The Coccidæ of Ceylon" is entirely free from defects. The fact that its preparation has extended over more than a quarter of a century precludes this, for since it was begun there have been radical changes in our methods and in our standards as well. Yet throughout it has always stood fully abreast and even in advance of the best contemporaneous work. Above all, the student, turning to its pages, can identify with relative certainty the species with which he may be dealing. With this much rendered possible, criticisms of any other features are but secondary. It is a splendid work, beautifully illustrated, well arranged and well printed. To its author all entomologists, whether economic or not, who are interested in the scale insects are under an obligation that can but illy be repaid. For the work has been a labor of love, its author's recompense the pleasure in its accomplishment.

With technical criticisms, of which there are some, I am not here concerned. Nor is it necessary to deal with the scope of the work, for practically all entomologists are familiar with this from the earlier parts. It is my desire simply to call attention to the appearance of the final part and to congratulate the author upon the completion of a huge task well done. Its completion clinches his hold upon a position that has really long been his, that of the foremost student of the Coccidæ.

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SPECIAL ARTICLES

PHOTOPERIODISM OF WHEAT: A DETERMINING FACTOR IN ACCLIMATIZATION

Garner and Allard (4), working with several species of plants, found that normally a plant could attain the flowering and fruiting stage only when the length of day was favorable, and suggest the terms *photoperiod* and *photoperiodism* to designate the favorable length of day and the response of a plant to the relative length of day and night. They conclude that, varying with species and variety, there is a critical photoperiod essential for the initiation of the fruiting stage of each plant, and that when this critical photoperiod does not occur the plant tends to remain vegetative.

In a preliminary experiment, the writer has found that a proper adjustment of the daily exposure to light, independently of temperature, will control the type of growth in the winter wheat plant and that by regulation of this factor it is possible to induce the jointing and the heading stages irrespective of season. In addition, this experiment has shown that there is a minimum stimulating photoperiod for the control of each of these stages of growth in the winter wheat plant, that for the succeeding stage not being the same as that for the preceding, and each photoperiod being, therefore, within certain limits critical for the stage concerned.

Although factors governing habits of growth, the distribution and the production of wheat have been the subject of many studies, the literature available has not revealed that any have ever considered, beyond the generalizations of Garner and Allard, the factors of photoperiodism as having a deciding influence. Circumstantial evidence, however, is available, which on analysis clearly indicates that these factors are important both with winter and with spring wheats. Grantham (5), Jardine (6) and Seivers and Holtz (11) have shown the tendency of winter wheat to a vegetative type of fall growth and have emphasized that the amount of this growth is dependent on time of seeding and available fertility. Gaines (10) and Neilson-Ehle (7) have found, in certain localities of the north temperate zone, the winter character to be inheritable as a simple Mendelian major. The northern limits of the winter wheat belt in the United States bear a significant relation to the northern limits of an active growing season of 150 days (1, 2). Smith, Root and Blair (3, 8, 12, 13, 14), in statistical studies of data from Ohio, found the dominant weather factor for winter wheat difficult to determine, but all agreed that the month of March was the critical period during which the effects of snowfall and temperature were later most reflected in condition and finally

in yields of winter wheat. Apparently, from their studies, the influences controlling the beginning of the development which determined final yielding ability of winter wheat occurred in March, regardless of how favorable growing conditions were for the rest of the season or how severe conditions during the preceding dormant period had been. Schafer and his associates report (9) that Hybrid 128 will not head out when planted later than March 11, and (10) that Turkey Red will joint in October when planted in April, while Hybrid 128 will not. McCall and Wanser (15) have found that Jones Fife and similar wheats joint early in the spring, while wheats of the Turkey Red type do not joint until a later date.

These observations indicate that the winter habit of wheat is caused by the absence of the critical stimulus which is essential for the initiation of the jointing stage. Though the response to the stimulus may be affected and altered by temperature and nutritional factors and, under field conditions, apparently, has been usually associated with these factors, the stimulus itself is, nevertheless, independent of them and for any given locality is controlled more by date than by current growing conditions. The observations of Schafer and his associates and of McCall and Wanser indicate that the date of the occurrence of the stimulus varies for different varieties, but for any given variety is fairly constant in a given locality.

In the light of the work of Garner and Allard and of the results secured by the writer, all of this evidence indicates, in the case of winter wheat, the stimulus for jointing to be a critical photoperiod having a maximum limit. The passing of this maximum limit results in a spring-sown winter variety failing to joint until the occurrence of shorter days during the following fall or succeeding spring. The season at which jointing then takes place depends on the occurrence of the length of day corresponding to the necessary photoperiod and an accompaniment of temperatures favorable for growth. In any case, heading, which must be preceded by jointing, is delayed until the following summer because of the longer day necessary to start this stage of development.

Although a preliminary experiment is always restricted in scope, the close agreement between the results of this experiment and the analysis of the supporting evidence makes possible a few safe tentative conclusions. The development of winter wheat requires a critical photoperiod for jointing and also a separate and distinct critical photoperiod for heading. Garner and Allard, working with dicotyledonous plants, mention but one critical photoperiod. Although varying with species and variety in the intensity of distinction, there probably are for most monocotyledonous and some dicotyledonous plants at least two critical photoperiods, one for starting culm or stalk development from the tillering or rosette stage and another for starting the heading or budding and blossoming stage.[1] The photoperiods for both responses probably have an optimum with a maximum and a minimum limit, but for winter wheat they are independent of each other, do not overlap and vary with variety. The northern limits of the distribution of winter wheat are probably very largely controlled by the relation of the date of the beginning of the active growing season to the date at which the longest day within the limits of the critical photoperiod for jointing occurs in that locality.

While the photoperiods for jointing and heading do not overlap and are entirely distinct in the case of winter wheat, they are not so distinct in the case of spring wheats. In the latter group the photoperiod for jointing is of greater magnitude than in the former, possibly without a maximum limit, and jointing and heading are possible under more nearly an identical photoperiodic stimulus. As a result such varieties when sown in the spring joint and head the same season. Photoperiodism, therefore, is the key to the distinction between winter and spring wheats.

Although no published evidence showing the effects of photoperiodism in the development of spring wheat is here referred to, there is, nevertheless, an abundance of available material, some of which will be mentioned in a later detailed report of experimental work now in

[1] In an article published in SCIENCE (June 2, 1922) since the preparation of this paper Garner and Allard recognize the two photoperiods for dicotyledonous plants but do not mention or consider monocotyledonous plants.

progress. This work, an enlargement of the preliminary experiment, is intended to cover certain phases of photoperiodism as it affects varietal adaptation and drouth resistance of both winter and spring wheats.

Whatever may be the final outcome from the standpoint of direct application in practical crop production, there can be no doubt that the present studies throw an entirely new light on crop and especially varietal response in a given locality, and that a knowledge of these factors will make possible a better and more logical interpretation of investigations in both crops and soils and will as well give a more sound basis for future work in crop adaptation and breeding.

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BIBLIOGRAPHY

1. Arnold, J. H., and Spafford, R. R.: "Farm practices in growing winter wheat," *U. S. Dept. Agr. Year Book*, 1919: 126.

2. Baker, O. E., and Strong, H. M.: "Arable land in the United States," *U. S. Dept. Agr. Year Book*, 1918: 436.

3. Blair, T. A.: "A statistical study of weather factors affecting the yield of winter wheat in Ohio," Abstract in *Exp. Sta. Record*, 42: 617, 1919.

4. Garner, W. W., and Allard, H. A.: "Effect of relative length of day and night and other factors on growth and reproduction in plants," *Jour. Agri. Res.*, 18: 1920.

5. Grantham, A. E.: "The tillering of winter wheat," *Bul. Del. Agr. Exp. Sta.*, 117, 1917.

6. Jardine, W. M.: "Effect of rate and date of sowing on yield of winter wheat," *Jour. Am. Soc. Agr.*, 8: 163, 1916.

7. Nielson-Ehle: Abstract in *Int. Rev. of Science and Practice of Agr.*, 1917: 233.

8. Root, C. J.: "Relation of snowfall to yield of winter wheat," Abstract in *Exp. Sta. Record*, 42: 321, 1919.

9. Schafer, E. G., Gaines, E. F., Barbee, O. E.: "Wheat production as influenced by variety, time of seeding and source of seed," *Wn. Agr. Exp. Sta. Bul. 159:* 33, 1921.

10. Schafer, E. G., *et al.:* Twenty-ninth annual report (for 1919), *Wn. Agr. Exp. Sta. Bul. 155:* 28, 1920.

11. Seivers, F. J., and Holtz, Henry: "The silt loam soils of eastern Washington and their management," *Wn. Agr. Exp. Sta. Bul. 166:* 25, 1922.

12. Smith, J. W.: "Agricultural meteorology," Abstract in *Exp. Sta. Record*, 35: 114, 115, 1916.

13. Smith, J. W.: "Effect of snow on winter wheat in Ohio," Abstract in *Exp. Sta. Record*, 42: 321, 1919.

14. Smith, J. W.: "Speaking of the weather," *U. S. Dept. Agri. Year Book*, 1920: 200, 201.

15. McCall, M. A., and Wanser, H. M.: Unpublished report of Adams Branch Station of Wn. Agri. Exp. Station, 1921.

IMPROVED METHODS IN NEAR INFRA-RED ABSORPTION STUDY

SOME twenty or more years ago Julius, Donath, Puccianti, Iklé, Coblentz and others were interested in the study of infra-red absorption in organic compounds. The apparatus they had to work with at that time made the study very tedious, and as Coblentz[1] has said, "usually after investigating half a dozen compounds the results have been given to the public" by the investigator. Using the electric arc, Nernst lamps and Zircon burners as sources of radiation, rock salt or quartz prisms for dispersion, and bolometers and radiometers for the detection of the radiation, these men succeeded in studying the absorption spectra of a great many organic compounds even far out into the infra-red. In fact, the biggest part of the work was done in the field beyond the so-called near infra-red, that is, beyond 30,000 Å.

But with such comparatively weak and unsteady sources of radiation, small dispersion, and unsatisfactory methods for the detection of this radiation, no high degree of accuracy in the measurements of absorption bands has been claimed. During the last twenty years very little work has been done in this field. Coblentz[2] has recently published a bulletin in which he gives certain data and curves for the absorption spectra of certain organic oils, both animal

[1] W. W. Coblentz: *Astrophysical Journal*, 20, 1904.

[2] W. W. Coblentz: Scientific Paper of the Bureau of Standards, No. 418.